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PHYSICS AND MATHEMATICS

No. 85

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LASERS AND MASERS

SPECTRAL MANIFESTATION OF MOBILITY LIMIT FOR EXCITONS IN $CdS_{1-x}Se_x$

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI
in Russian Vol 37, No 8, 20 Apr 83 (manuscript received 12 Mar 83)
pp 390-392

PERMOGOROV, S. A., REZNITSKIY, A. N., VERBIN, S. Yu. and LYSENKO, V. G.,
Physico-Technical Institute imeni A. F. Ioffe, USSR Academy of Sciences

[Abstract] A study was made of excitons (localized concentration fluctuations) in $CdS_{1-x}Se_x$ solid solution and of the polarization of their luminescence. Specimens of hexagonal crystals were excited by polarized radiation from an Ar^+-laser or a dye (coumarin 152) laser. Luminescence from cleavage planes or growth faces perpendicular to the optical axis was recorded and the degree of its polarization measured as the ratio $\rho = (I_{\parallel} - I_{\perp})/(I_{\parallel} + I_{\perp})$ ($I_{\parallel}$, $I_{\perp}$- luminescence intensities in polarization respectively parallel and perpendicular to polarization of the exciting light). These measurements revealed a dependence of the degree of luminescence polarization on the frequency of the exciting light. Polarization of luminescence, attributable to a random orientation and "latent anisotropy" of potential wells which localize an exciton, is in this case preceded by splitting of the Γ_5 exciton level without subsequent transfer of excitation from one well to another. The sharp decrease of polarization on the short-wave side of the spectrum corresponds to depolarization as a result of transfer of excitation from an initial level to a level in another potential well and is interpreted here as the beginning of exciton mobility, the probability of exciton migration increasing with higher excitation frequency. This mobility threshold also coincides with a sharp upward jump of luminescence intensity on the short-wave side. The decrease of polarization on the long-wave side of the spectrum cannot be explained by migration of excitons, but perhaps by a change in anisotropy. Two possible mechanisms are proposed here. One is interaction of adjacent potential wells. Another is deepening of localization in deep but narrow potential wells so that only holes become localized, while electrons have an averaging effect because of the large radii of their orbits. The authors thank Ye. L. Ivchenko, G. Ye. Pikus, E. I. Rashba and V. B. Timofeyev for discussing the results.
Figure 1, references 7: 4 Russian, 3 Western.
[45-2415]

EFFECT OF ONE-DIMENSIONAL DISORDER ON EXCITON STATES IN SEMICONDUCTOR SOLID SOLUTIONS

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 37, No 8, 20 Apr 83 (manuscript received 24 Feb 83) pp 372-375

MASLOV, A. Yu., SUSLINA, L. G., ARESHKIN, A. G., MELEKHIN, V. G. and FEDOROV, D. L., Physico-Technical Institute imeni A. F. Ioffe, USSR Academy of Sciences

[Abstract] There are two kinds of disorder in semiconductor solid solutions: three-dimensional disorder due to concentration fluctuations and one-dimensional disorder due to stacking defects produced in the structure when two compounds with different crystal lattices are mixed, both disorders giving rise to a random potential distribution and to a blurring of band boundaries. A theoretical solution to the three-dimensional problem is necessarily approximate, but the one-dimensional problem can be and has been solved exactly. As a test case the authors consider the effect of one-dimensional disorder on the exciton states in the $Zn_{1-x}Mg_xS$ system over the entire $0 < x < 0.12$ range of existence of sphalerite-wurtzite phase transition. The disorder here was measured by two methods, birefringence and exciton spectroscopy at low temperatures (77 and 2 K). The location and the widening of the exciton ground line in the reflection spectrum vary as functions of the magnesium content x, the location of this line shifting from 3.87 eV at $x = 0$ to 3.96 eV at $x = 0.12$ and its half-width peaking at $x = 0.056$ and $x = 0.062$ to approximately 20 meV. This is confirmed theoretically on the basis of the Schroedinger equation of motion for an exciton in a one-dimensional random potential and the equation

$$\frac{dE_A}{dx} = \frac{\partial E_A}{\partial x} + \frac{\partial E_A}{\partial \alpha}\frac{d\alpha}{dx} = 1.21 \text{ eV for } Zn_{1-x}Mg_xS \text{ with stacking defects } (E_A-$$

location of exciton ground line A, $\alpha = \Delta n/\Delta n_0$- degree of anisotropy, Δn- birefringence in $Zn_{1-x}Mg_xS$, Δn_0- birefringence in ZnS with wurtzite structure). The authors thank I. P. Ipatova and A. L. Efros for discussing the results. Figures 2, references 8: 7 Russian, 1 Western.
[45-2415]

ANABATIC DIFFUSION OF VACANCIES AND INSTABILITY OF IRRADIATED SUBSTANCE

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI
in Russian Vol 37, No 6, 20 Mar 83 (manuscript received 7 Jan 83) pp 278-281

DEVYATKO, Yu. N. and TRONIN, V. N., Moscow Institute of Engineering Physics

[Abstract] There is experimental evidence of unstable behavior of a substance after long exposure to ionizing radiation, this instability being manifested in formation of vacancies and precipitation of new phases. A theoretical interpretation requires a phenomenological approach, inasmuch as the equations describing the kinetics of glissile point defects do not admit unstable solutions for the defect concentration unless the mechanism of anabatic diffusion of vacancies against the substitutional impurity gradient is specifically added to the mechanism of anabatic impurity diffusion. Only two of the complete system of these kinetic equations are needed, namely the equations for the rate of change of vacancy concentration and for the rate of change of complex (substitutional impurity) concentration respectively. These equations are solved, assuming the existence of homogeneous and quasi-steady solutions for the concentration of point defects $n_1^{(0)}$ ($1 = V,I,p,m$) (V- vacancies, I- interstitial atoms of host substance, p- interstitial atoms of impurity, m- substitutional atoms of impurity). Assuming that deviations from the quasi-steady solutions are small, the solution to these equations is sought in a form corresponding to the variation of vacancy concentration and admitting linear analysis. Such a solution indicates two possible modes of instability in the given model, namely rise of local vacancy concentration with formation of vacancy pores or rise of local complex concentration. The structure of these instabilities can be examined more thoroughly when the constraint of small deviations from the quasi-steady solutions is removed. The authors thank I. S. Shapiro for valuable comments. References 3: 2 Russian, 1 Western.
[43-2415]

ANOMALOUSLY NARROW PEAK OF PERMITTIVITY NEAR DIFFUSE PHASE TRANSITION IN $Cd_2Nb_2O_7$

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian
Vol 37, No 6, 20 Mar 83 (manuscript received 15 Dec 82) pp 257-259

SMOLENSKIY, G. A., SALAYEV, F. M., KAMZINA, L. S., KRAYNIK, N. N. and DOROGOVTSEV, S. N., Physico-Technical Institute imeni A. F. Ioffe, USSR Academy of Sciences

[Abstract] The permittivity and loss tangent of cadmium pyroniobate were measured with high precision over the 193-213 K temperature range, while its single crystals with either [111] or [001] orientation were first cooled and then heated over this range at a rate of 0.05 K/min. The measurements were made with an E4-7 Q-meter at an electric field intensity of 200 V/m and at two frequencies: 50 and 400 kHz. The anomalous narrow

permittivity peak did not shift significantly with change of frequency, but an ~ 0.6 K hysteresis of the temperature dependence was detected indicating a phase transition of the first kind near a phase transition of the second kind. The anomalous peak shifted to an ~ 1.5 K higher temperature after specimens had been heated at 700-800 K and returned to their original temperature 5-10 days later. Noteworthy is a change in the domain structure occurring within the 201-205 K interval, characterized by diffusion of the boundaries with apparent breakup into subdomains. The narrow permittivity peak at 201 K can, accordingly, can be interpreted as a consequence of transition from a phase with a diffuse fine-domain structure stabilized by defects to a phase with a ferroelectric domain structure. The authors thank Ye. S. Sher for growing the single crystals of cadmium pyroniobate and V. A. Isupov for helpful discussions. Figures 2, references 6: 5 Russian, 1 Western.
[43-2415]

LONG-WAVE LIGHT-EMITTING DIODES MADE OF $InAs_{1-x-y}Sb_xP_y$ SOLID SOLUTIONS AND OPERATING WITHOUT COOLING

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 7, 12 Apr 83 (manuscript received 2 Feb 83) pp 391-395

YESINA, N. P., ZOTOVA, N. V., MATVEYEV, B. A., STUS', N. M., TALALAKIN, G. N. and ABISHEV, T. D., Physico-Technical Institute imeni A. F. Ioffe, USSR Academy of Sciences, Leningrad

[Abstract] Solid solutions of the InAs-InSb system are excellent materials for light-emitting diodes used in semiconductor optoelectronics and in gas analyzers. However, the Auger recombination coefficient increases with increasing antimony content and is maximum in the $InAs_{0.7}Sb_{0.3}$ p-n structure most suitable as radiation source. This drawback can be overcome by the use of quaternary solid solutions $InAs_{1-x-y}Sb_xP_y$, namely by adding phosphorus so that the spin-orbital splitting energy Δ will decrease faster than the energy gap E_g will increase and thus resonance between them will be avoided. Specimens of such light-emitting diodes for use in gas analyzers at 300 K were produced experimentally by epitaxy from the liquid phase, p-n films deposited on n-InAs substrates with $n = (1\text{-}3)\cdot10^{18}$ cm^{-3} and the p-region formed by alloying the solution-melt with zinc or manganese. The phosphorus content was varied over the $0.05 \leq y \leq 0.13$ range and the antimony content was held at the $x \sim 0.08$ level. The mismatch between lattice periods did not exceed ±0.0071 Å and the dislocation density in the best specimens reached $(5\text{-}8)\cdot10^4$ cm^{-2}. The capacitance of these diodes at zero bias voltage was $5\cdot10^5$ pF/cm^2. Their current-voltage characteristics and luminescence spectra were measured at 77 and 300 K, with the maximum electric field intensity $5\cdot10^3$ V/cm at zero bias. The results indicate a high ratio of "recombination-generation" current component in the space-charge region to "diffusion" current component in

both n- and p- regions at 77 K, also a forbidden band which becomes much narrower with rising temperature. The luminescence spectra of these diodes cover the 3-5 μm infrared range, coinciding with the absorption range of many gases. A radiation power of 200 μW at 2% efficiency is attainable with a constant d.c. excitation of 15 A/cm^2, a radiation power of 2-5 mW is attainable with excitation by current pulses of 1000 A/cm^2 and 20 μs duration at a repetition rate of 20 Hz. Figures 2, references 6: 5 Russian, 1 Western.
[49-2415]

CHANGE IN REFLECTIVITY OF ZINC UPON LASER HEATING OF NANOSECOND DURATION

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 5, 12 Mar 83 (manuscript received 4 Oct 82) pp 277-281

ZHIDKOV, V. V., IVLEV, G. D., MALEVICH, V. L. and MORGUN, Yu. F.,
Institute of Electronics, BSSR Academy of Sciences, Minsk

[Abstract] The anomalous absorption characteristics of zinc in the red and near infrared range of the spectrum are, along with changes in its reflectivity during heating by nanosecond laser pulses, an important factor in the process of laser annealing of "Zn film on GaAs substrate" structures during formation of p-n junctions. An experimental study of the reflectivity of zinc under such conditions was made using wafers of extra-pure zinc with mechanically polished mirror surfaces. These specimens were irradiated with annealing radiation from a monopulse ruby laser and with probing radiation, the latter consisting of fundamental-mode λ_{prob} = 1.06 μm and second-harmonic λ''_{prob} = 0.53 μm radiation from a free-emission quasi-continuous neodymium laser polarized in the incidence plane and impinging at an incidence angle of 30°. The specularly reflected radiation was recorded by ELU-FTI photomultiplier-photoreceivers and on an S1-7 two-beam oscillograph. A microstructural examination revealed point defects in the form of 10-20 μm microcavities due to vaporization, perdominantly around mechanical defects constituting regions of higher absorptivity. The reflection coefficient for 1.06 μm waves was found to have changed mostly under a laser monopulse of 1-4 J/cm^2 energy, namely to have increased by a factor of 1.5 and to remain so high for a period of time exceeding the duration of the laser monopulse. A slight irreversible decrease of the reflection coefficient for 0.53 μm waves and no change in the reflection coefficient for either wavelength under monopulses of $W \leq 0.5$ J/cm^2 energy were observed. The experimental results are correlated with theoretical results based on the equation of heat conduction with a surface source, describing the heating and the melting of zinc in the one-dimensional approximation. This equation was solved by the finite-difference method with smoothing of coefficients in the implicit scheme, with a 0.02 μm step along the space coordinate and a 1 ns step along the time coordinate. Figures 2, references 9 Russian.
[47-2415]

UDC 621.373.8

DISCHARGE-PUMPED HIGH PULSE RATE EXCIMER LASER

Tallinn IZVESTIYAAKADEMII NAUK ESTONSKOY SSR: FIZIKA, MATEMATIKA in Russian
Vol 32, No 1, Jan-Mar 83 (manuscript received 12 Jan 82, revised 2 Mar 82)
pp 109-113

[Article by A. Vill, T. Klementi, V. Mikhkel'soo and V. Altukhov]

[Text] UV excimer lasers, especially discharge-pumped high pulse rate lasers, are distinguished by simplicity of construction, high efficiency, high peak power and high average power [1-5], thanks to which they are being utilized increasingly in science and for practical purposes. They are being used, for example, for pumping dye lasers, purification of substances in selective laser chemistry, etc.

Our objective was to develop and investigate experimentally a compact excimer high pulse rate laser with relatively high efficiency and high pulse energy, and to select optimal parameters for the power system and laser radiation through model calculation of oscillograms of the discharge current and circuit voltage.

The electrical circuit of the ELI-2 high pulse rate excimer laser is a traditional TEA-circuit [6] with the working gas blown transversely between the electrodes. The Blumline oscillator employs type KVI-3 capacitors, with a TGI-1-1000/25 thyratron as the switch. It is important to note that "peaking" capacitors are connected in parallel with the discharge circuit, making it possible to increase the efficiency by a factor exceeding 1.5 by selecting optimal capacitance values. Pre-ionization is done by UV illumination by a capacitive discharge through a dielectric (glass in the present case). The pre-ionizers are placed as close as possible to the discharge space. The distance between electrodes is about 20 mm, the electrodes are 600 mm long, and the radius of curvature of both electrodes is 20 mm. The pre-ionization method employed provides a uniform capacitive discharge and elevated diffuseness of the basic discharge. Uniformity of the capacitive discharge prevents erosion of the electrodes, which is important for long-life periodic pulsed lasers.

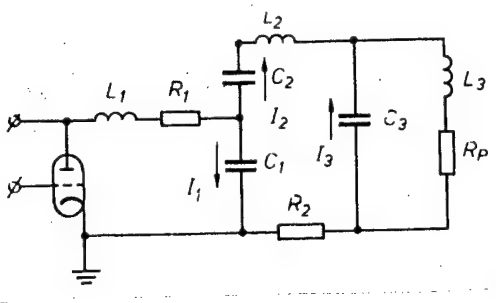

Fig. 1. Equivalent electrical circuit of laser power supply system

The laser is constructed as two modules: a) a radiator with a ballast space and proportional gas replacement and dispensing system, and b) a control unit with power supply. The latter allows the laser to operate at a pulse repetition frequency of up to 100 Hz. The high voltage capacitors are charged by an impulse transformer with storage capacitors connected to the primary winding. The switch is a TChI-100 thyristor. Gas is blown through the laser cuvette by three parallel axial fans which are turned in the working space by means of magnetic clutches. The ballast space comprises 100 liters, and the power supply has efficiency of approximately 70%.

In order to calculate the oscillograms of the current and voltage of the discharge circuit of the laser power system it was necessary to solve a system of Kirchhoff equations, which are conveniently written as follows for our electrical discharge system (Fig. 1):

$$\dot{I}_1 = F/L_1 - q_1/L_1C_1 - R_1(I_1+I_2)/L_1, \tag{1}$$

$$\dot{I}_2 = -F/L_2, \quad F = R_2I_2 - q_1/C_1 + q_2/C_2 - q_3/C_3, \tag{2}$$

$$\dot{I}_3 = F/L_2 - q_3/L_3C_3 - R_p(I_2+I_3)/L_3. \tag{3}$$

The currents I_1, I_2, I_3 and the initial conditions for the charges and currents $I_i(0)$ (i=1,2,3) for a given initial voltage V_0 are defined by the relationships

$$I_1 = \dot{q}_1, \quad I_1(0) = 0, \quad q_1(0) = C_1V_0,$$

$$I_2 = \dot{q}_2, \quad I_2(0) = 0, \quad q_2(0) = C_2V_0,$$

$$I_3 = \dot{q}_3, \quad I_3(0) = 0, \quad q_3(0) = 0.$$

The values of the resistance R_1 and inductances L_1, L_2 and L_3 of the discharge circuit

$$R_1 = 0.1 \text{ Ohms}, \quad L_1 = 2 \cdot 10^{-7} \text{ H},$$
$$L_2 = 2 \cdot 10^{-9} \text{ H}, \quad L_3 = 5 \cdot 10^{-9} \text{ H}$$

were selected on the basis of general construction considerations and the proposed average power of a laser (approximately 10 W), and the values of the other parameters C_1, C_2, C_3, R_2 and R_p were selected in accordance with the principle of maximum attainable efficiency and best agreement between calculated discharge oscillograms and experimentally observed oscillograms of voltage across "peaking" capacitance C_3. The resistance of the plasma R_p was approximated by a step with R_p dropping off to 0.5 Ohms at the moment of breakdown of the discharge interval approximately 80 nsec after initiation of switching. The qualitative and quantitative agreement in the behavior of the calculated and measured oscillograms (cf. Fig. 2) indicates the applicability of the approximation we used for $R_p(t)$. In selecting the value of C_3, in addition to the optimal coefficient of transfer of the energy stored in the capacitors to the plasma

$$K = \varepsilon_b / \varepsilon_0, \tag{4}$$

where $\varepsilon_0 = V_0^2$, allowance was made for achieving maximum efficiency, limiting the quantity C_3 from below. The energy contribution to the discharge was taken into account prior to the first zero-crossing of the discharge current $I_p(t) = I_2(t) + I_3(t)$.

Values of $R_2 \leq 0.01$ Ohms, $C_1 = 9 \cdot 10^{-9}$ F, $C_2 = 19 \cdot 10^{-9}$ F, $C_3 = 10 \cdot 10^{-9}$ F were found, which provide maximum output of generation energy with a standard working mixture of HCl:Xe:He (0.2:4:95.8%). By varying the parameters of the power supply, it was possible to select a favorable discharge mode with sufficiently steep voltage rise (approximately 18 kV over 80 nsec) and with a short (approximately 20 nsec) but strong (approximately 25 kA) discharge current pulse (cf. Fig. 2). By using the values found for C_1 and C_2, and the breakdown voltage measured for this mixture $V_0 = 24$ kV, we obtain efficiency of approximately 0.9% for an XeCl laser.

When working with XeF, the halogen donor was NF_3, since the glass textolite insulation of the discharge chamber did not permit fluorine to be used. Lasing was obtained with a mixture of NF_3:Xe:He (1:3:500) at

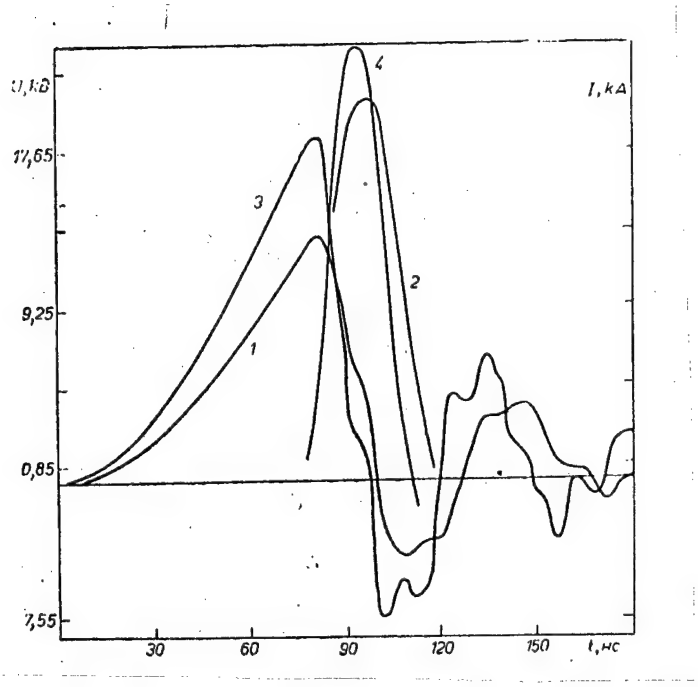

Fig. 2. Time dependency of discharge current (2,4) and voltage (1,3): curves 1 and 2 for $C_3=10^{-18}$ F, curves 3 and 4 for $C_3=5\cdot10^{9}$ F.

a pressure of 2.3 atmospheres. The pulse energy at pulse repetition frequencies of up to 100 Hz was 100 mJ, with average power of 10W. Unfortunately, the service life of the mixture containing NF_3 with the purity we were able to achieve (approximately 96%) is fairly short, and with a ballast volume of 100 liters totals approximately $3\cdot10^4$ pulses (with the generation energy cut in half (Fig. 3)). In determining the service life, voltage oscillograms were recorded in parallel, for which the appearance remained practically unchanged as the working mixture aged.

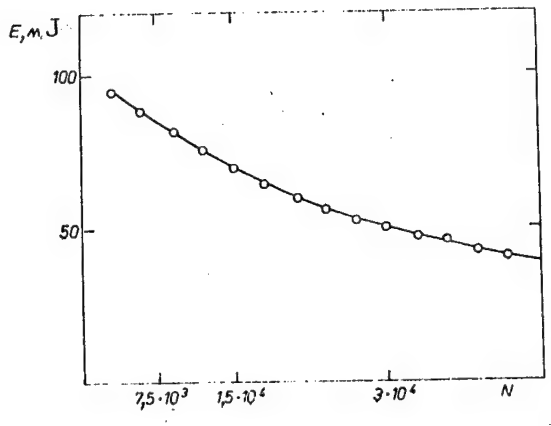

Fig. 3. Pulse lasing energy E as function of number of pulses N working with XeF

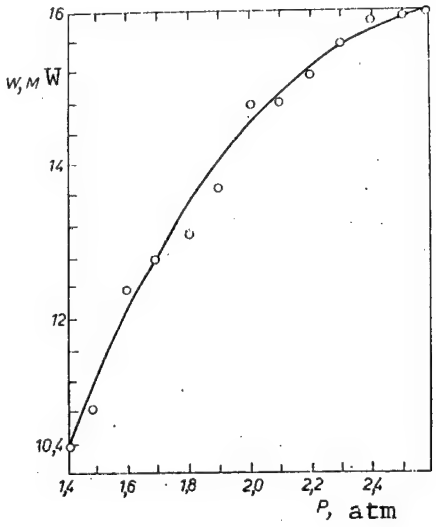

Fig. 4. Pulse power W as function of pressure P working with XeCl

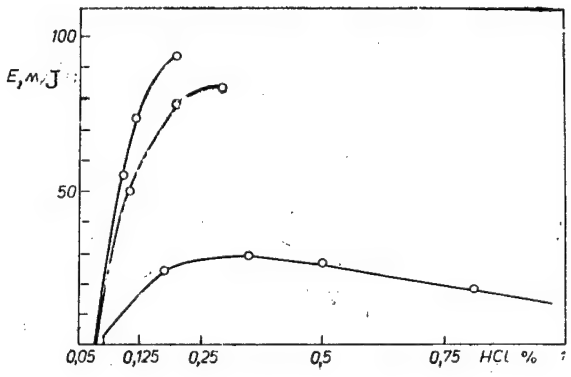

Fig. 5. Pulse radiation energy E as function of composition of working mixture HCl:Xe:He

In the case of XeCl for a standard HCl:Xe:He mixture the pulse radiation energy is 75 mJ, with efficiency of approximately 0.9% and pulse repetition frequency of up to 100 Hz. The continuous operation duration with XeCl amounts to 10^6-10^8 pulses, which is significantly longer than for XeF. The shape and duration of the lasing pulse were recorded with the help of an FEK-29 and an S7-13 stroboscopic oscillograph. The lasing pulse duration of the XeCl laser is approximately 15 nsec. When the pressure drops from 2.6 to 1.4 atm the XeCl pulse power drops from 16 to 10.4 MW (cf. Fig. 4).

In analyzing the relationship between output energy and composition of working gas a scheme for proportional dispensing of the components and spraying them into the working chamber was employed. This made it possible to regulate the composition of the components to within 0.005%. Figure 5 shows the output energy as a function of HCl content for various doses of Xe (0.6, 2.3, 3.5%). For small doses of HCl the nature of the voltage oscillograms is practically independent of the composition of the working mixture; however, when the content is increased 1% the shape of the voltage pulse changes sharply, and the discharge becomes highly unstable with a large number of streamers.

Conclusions

The ELI-2 discharge-pumped high pulse rate excimer laser was developed. System efficiency of about 1% was achieved by optimal selection of the parameters of the power system. With pulse repetition frequencies below 100 Hz, pulse radiation energy of 75 mJ was obtained for XeCl, and 100 mJ for XeF.

During the development it was also possible to solve a number of engineering and technical problems associated with improving the operating reliability and convenience of maintenance of the laser.

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CSO: 1862/55

TUNABLE FAR IR ZONE HETEROLASER WITH WAVELENGTH TO 46.2 μm

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI
in Russian Vol 37, No 9, 5 May 83 (manuscript received 4 Mar 83) pp 422-424

KURBATOV, L. N., BRITOV, A. D., KARAVAYEV, S. M., SIVACHENKO, S. D., MAKSIMOVSKIY, S. N., OVCHINNIKOV, I. I., RZAYEV, M. M. and STARIK, P. M.

[Abstract] A report is presented on a significant expansion in the spectral bandwidth of laser diodes into the far IR region. Optical long wave laser radiation at 46.2 μm has been achieved in heterolasers based on a four-component PbSnTeSe solid solution. $(PbSe)_{0.80}(SnTe)_{0.20}$ Single crystals were grown from the vapor phase with an initial hole concentration of about 10^{19} cm^{-1}. Subsequent annealing in metal vapors reversed the conductivity type and reduced the carrier concentration to 10^{17}-10^{18} cm^{-3}. Laser heterostructures were manufactured by photostimulated gas epitaxy. A charge of $PbTe_{0.68}Se_{0.32}$ was used to apply the wideband epitaxial p-type layer. p- and n-electrodes of the heterostructures were obtained by chemical precipitation of gold. The emission spectra of the laser diode are illustrated. One characteristic feature of the laser diodes studied is comparatively slight (factor of three) reduction in threshold current density as temperature drops from 78 to 6 K. The authors do not feel that the wavelength obtained is by any means the limit for laser diodes of this type. Figures 2, references 4: 3 Russian, 1 Western.
[52-6508]

COHERENT EFFECTS IN GENERATION AND AMPLIFICATION OF ULTRASONIC PULSES IN Nd:YAG AND RUBY AT LOW TEMPERATURES

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI
in Russian Vol 37, No 5, 5 Mar 83 (manuscript received 31 Jan 83)
pp 229-231

VARNAVSKIY, O. P., KIRKIN, A. N., LEONTOVICH, A. M., MIRZOYAN, R. G., MOZHAROVSKIY, A. M. and SATAYEV, I. R., Physics Institute imeni P. N. Lebedev, USSR Academy of Sciences

[Abstract] The coherent interactions of light pulses with resonant media have been studied for absorbing media. This article presents studies in

gases in the nanosecond length range. The results agree in general terms with the results of the much more numerous theoretical works dedicated to this problem. The experimental results presented in this work deal with the generation and amplification of ultrashort pulses in Nd:YAG and ruby at low temperatures. Amplification was studied at the junction between R_1-Y_1 components of the multiplex $^4F_{3/2}$-$^4I_{11/2}$ using rods measuring 5 x 60 and 8 x 80 mm pumped with flash lamps cooled to about 100 K by nitrogen vapor. Estimates of the inverse of heterogeneous width from spectroscopic data yield values of 20 psec and 150 psec, respectively. Input pulses were supplied by a self-mode-locked Nd:YAG laser. Pulse length was about 80 psec, energy about 1 mJ, beam diameter 2 mm. Coherent effects in generation and amplification of picosecond pulses in condensed media have not been previously described in the available literature. Figures 2, references 12: 9 Russian, 3 Western.
[51-6508]

LITHIUM NIOBATE CRYSTAL LASER WITH FREQUENCY DEGENERATE PUMPING

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI
in Russian Vol 37, No 5, 5 Mar 83 (manuscript received 1 Feb 83)
pp 243-247

ODULOV, S. G. and SOSKIN, M. S., Institute of Physics, Ukrainian SSR Academy of Sciences

[Abstract] Lasing by interaction of two coherent light beams in a medium with nonlocal response is performed in lithium niobate crystals doped with iron with excitation by continuous He-Cd laser radiation. The diffusion nonlinearity observed previously in $BaTiO_3$ crystals was used, nonlocal nonlinearity specific for activated crystals, related to spatially oscillating photogalvanic currents. Lasing was obtained in plane parallel specimens of reduced lithium niobate crystals with 0.03 wt.% iron, 0.4 cm thick. In all cases a sharp rise in light induced pumping radiation scattering was first observed, an analog of the superluminescence in ordinary laser systems. A brighter spot was then developed, corresponding to the lasing beam oriented perpendicular to the ends of the specimen. The intensity of radiation scattered at other angles decreased greatly. The angular divergence of the generated beam in most cases was about 5 degrees, but it was structured and frequently contained a core with divergence close to that of the pumping beam, about 30 minutes. Lasers based on the principle of dynamic holography open new prospects for the correction of the wave fronts of laser beams in real time and effective generation of beams with assigned space-angle structure. Figures 2, references 17: 8 Russian, 9 Western.
[51-6508]

ONE MECHANISM OF DEVELOPMENT OF NONLINEAR CURRENT-POWER CHARACTERISTIC SPECIFICS IN FLAT HETEROLASERS

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 8, 26 Apr 83 (manuscript received 8 Jan 83) pp 449-452

SURIS, R. A. and SHTOFICH, S. V.

[Abstract] A study is made of a simple model of a flat heterolaser in which the current I is homogeneously pumped in an undoped active layer in a band of width α_1 beneath a junction created by a concentration of free electrons. The remainder of the active layer is not pumped. The radiation of the laser propagates both through the pumped area beneath the contact and the unpumped areas on either side. Equations are derived which explain the increase in slope of the current-power characteristic with an increase in laser mirror reflection coefficient. The increase in laser radiation power and related deformation of the laser waveguide may result in the development of new transverse modes and generation channels. References 8: 2 Russian, 6 Western.
[50-6508]

CURRENT-VOLTAGE CHARACTERISTICS OF STRIP HETEROLASERS

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 8, 26 Apr 83 (manuscript received 8 Jan 83) pp 452-455

SURIS, R. A. and SHTOFICH, S. V.

[Abstract] Attention is drawn to one mechanism of development of specifics in characteristic U(I) in strip lasers. Absorption of radiation in unpumped areas of the active layer leads to nonlinear specifics of P(I). The influence of this mechanism on characteristic U(I) is studied. A simple equivalent circuit of a strip laser is illustrated and studied. The laser operates without pecularities at the lasing threshold only where $\theta < \theta_1$. The development of the specifics of cha acteristic U(I) after training of the laser can be explained by the decrease in doping of the active layer due to diffusion of impurities from emitters or self-compensation. U(I) curves at the threshold of excitation of each transverse mode may have the same specifics as are possible at the threshold of the primary mode. Figure 1, references 6: 3 Russian, 3 Western.
[50-6508]

INJECTION BRAGG HETEROLASER WITH HIGH TEMPERATURE STABILITY OF RADIATION WAVELENGTH

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 8, 26 Apr 83 (manuscript received 17 Feb 83) pp 456-460

GUREVICH, S. A., NESTEROV, S. I., PORTNOY,,Ye. L., SKOPINA, V. I. and TIMOFEYEV, F. N., Institute of Physics and Technology imeni A. F. Ioffe, USSR Academy of Sciences, Leningrad

[Abstract] The first report is presented on the creation of an injection heterolaser with distributed Bragg mirror based on a Ta_2O_5 dielectric waveguide. Significantly weaker variation in position of lasing line on temperature is observed in this laser than in ordinary distributed Bragg mirror lasers based on semiconductor waveguides. The laser was made of a Ga(Al)As heterostructure in which the waveguide consisted of three layers with the narrowest GaAs layer in the center, providing for excitation of the zero waveguide mode. The spectral position of the distributed reflection band in this laser depends on temperature as the effective index of refraction of the dielectric waveguide depends on the temperature. In the area of transparency of the waveguide material this dependence may be quite weak, explaining the high temperature stability of lasing lines.
Figures 3, references 7: 3 Russian, 4 Western.
[50-6508]

FEASIBILITY OF FORMING SHORT LASER PULSES IN COHERENT-EMISSION MODE

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 37, No 7, 5 Apr 83 (manuscript received 16 Feb 83) pp 313-316

NAZARKIN, A. V., POLUEKTOV, I. A. and SOBEL'MAN, I. I., Institute of Physics imeni P. N. Lebedev, USSR Academy of Sciences

[Abstract] It is demonstrated theoretically that the energy of an $n\pi$-pulse passing through a resonant absorbing medium can be efficiently transferred to a pulse at the frequency of a neighboring transition and with a much shorter duration. A medium of 3-level atoms is considered, for specificity, and in it propagating a steady 2π-pulse at frequency $\omega_0 \approx \omega_{31}$ and of duration τ_0 followed by a weak signal pulse at frequency $\omega_s \approx \omega_{32}$ and of duration $\tau_s < \tau_0$. The group velocity v_0 of the pump pulse is much lower than the phase velocity of light c in the medium, but the group velocity of the signal pulse is $v_s \approx c$. A solution of the system of corresponding self-consistent field equations yields the condition for signal amplification through energy transfer from the pump pulse: $(\omega_s/\omega_0)(\mu_{23}/\mu_{13})^2 > \tau_0/\tau_{s0}$ with corresponding pair of transitions $1 \rightarrow 3$, $3 \rightarrow 2$ ($\mu_{23}/\mu_{13} >> 1$) (μ_{13}, μ_{23}- dipole moments of transitions). The quantity

$\theta_s = (\mu_{23}/\hbar) \int_{-\infty}^{\infty} |E_s| dt$ (E_s- complex pulse amplitude) can be equal to π, such

a π-pulse being stable in a coherently amplifying medium. Numerical calculations confirm this, also that the energy transfer is negligible when $\theta_s << 1$. When $1 \sim \theta_s < \pi$, the energy transfer is appreciable and the duration of the signal pulse remains almost constant $\tau_s \sim \tau_{s0}$. Figures 2, references 3 Russian.
[44-2415]

LASER MODE LOCKING BY TRAVELING-ACOUSTIC-WAVE MODULATOR

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 7, 12 Apr 83 (manuscript received 12 Jan 83) pp 440-443

KRAVTSOV, N. V., MAGDICH, L. N., SHELAYEV, A. N. and SHNITSER, P. I.

[Abstract] The feasibility of forced locking of laser modes on a traveling acoustic wave, by means of a modulator with diffractional optoacoustic feedback, has been established in an experiment with a YAG:Nd^{3+} ring laser. The optoacoustic modulator consisted of a 36°Y-cut $LiNbO_3$ piezoradiator, an acoustic waveguide wedge made of fused quartz with Brewster faces, and a sound absorber. This modulator operated in the Bragg diffraction mode. Radiation diffracted by the modulator could be fed back to it and to the main laser resonator in three ways: 1) by means of one reversing mirror; 2) by means of two mirrors forming a linear resonator with a diaphragm between them; 3) by means of three mirrors forming another ring resonator. The piezoradiator was excited by a microwave oscillator through an amplifier. A condition for stable mode locking is space-time overlap of ultrashort light pulses propagating in the laser ring resonator and ultrashort light pulses injected by the feedback, which can be achieved by matching the optical lengths of feedback branch and laser perimeter. No forced mode locking is possible without feedback, but has been achieved on a standing acoustic wave in an earlier experiment. Figure 1, references 3 Russian.
[49-2415]

MECHANISMS OF INTERACTION OF NANOSECOND LASER RADIATION AND METALS

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 7, 12 Apr 83 (manuscript received 14 Apr 82, after final editing 28 Dec 82) pp 395-399

SUD'YENKOV, Yu. V., FILIPPOV, N. M., VOROB'YEV, B. F. and NEDBAY, A. I.

[Abstract] Interaction of radiation from a nanosecond laser with metals was studied by the acoustic method. Copper and aluminum specimens were irradiated over a polished surface area 0.5 cm in diameter with pulses at the $\lambda = 0.69$ μm wavelength of $3 \cdot 10^{-8}$ s duration. The power density of

incident radiation flux, varied over the $1 \cdot 10^6 - 3 \cdot 10^8$ W/cm^2 range through regulation of the pumping power in two amplifier stages, was measured with a calorimeter. The acoustic signals emitted by the target surface upon impact of radiation pulses were recorded by an oscillograph after passing through a piezoelecgric transducer operating in the short-circuit mode. Also recorded were signals from an FEK-09 photodiode measuring the pulses of light specularly reflected by the metal surface and signals from an FEU-87 photomultiplier indicating the time of flare-up. The acoustic signals from an FEU-87 photomultiplier indicating the time of flare-up. The acoustic signals were characterized by compression (positive) and rarefaction (negative) jumps in time, their magnitude and time of occurrence depending on the rarefaction (negative) jumps in time, their magnitude and time of occurrence depending on the radiation flux density. The intensity of specular reflection was also found to depend on the radiation flux density. Evidently phase transitions, melting and subsequent evaporation with attendant strong absorption of radiation followed by optical breakdown (at 90 MW/cm^2 for copper) play a significant role in this process. At radiation flux densities above the breakdown level the acoustic signal ceases to increase and becomes unipolar compressive and specular reflection of light weakens, the flame acting as a shield over the metal surface. This situation prevails till the radiation flux density has reached another level at which the "piston-flame" expands generating a strong shock wave and a second peak in the acoustic signal. Figures 3, references 9 Russian. [49-2415]

COHERENCE OF RADIATION FROM SEMICONDUCTOR LASER WITH EXTERNAL REFLECTING ELEMENT

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 6, 26 Mar 83 (manuscript received 29 Nov 82) pp 348-352

SURIS, R. A. and TAGER, A. A., Institute of Radio Engineering and Electronics, USSR Academy of Sciences, Moscow

[Abstract] It has been established experimentally that the coherence path of radiation from a semiconductor laser can be lengthened by means of an external selective mirror. The narrowing of the emission line with the mirror at a distance from the isolated laser shorter then the coherence path was already calculated. Here the narrowing of the emission line is calculated for the case of the mirror at a distance longer than the coherence path. Calculations are based on the "short" equation describing the field in the active zone of a single-mode semiconductor laser in the approximation of very weak coupling with a "mirror" (e.g. a dust mote). The selectivity of the mirror is assumed to be negligible within a frequency range of the order of several intermode separations in the external resonator and no windows are assumed to form in the amplification line with resulting multimode emission. The equation is solved by the Langevin method for the time coherence function, taking only phase fluctuations into account. The conditions are established under which the mirror becomes effective and the

coherence function approaches its asymptotic limit without oscillations. The emission spectrum as well as its evolution with increasing pump energy and increasing length of the coherence path, from multimode to single-mode, are analyzed on this basis with the aid of Fourier transformation of the coherence function. Figures 2, references 3 Western.
[48-2415]

FAST-TUNABLE LASER BASED ON OPTOACOUSTIC FILTER

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 5, 12 Mar 83 (manuscript received 2 Nov 82) pp 264-267

ABRAMOV, A. Yu., MAZUR, M. M. and PUSTOVOYT, V. I., All-Union Scientific Research Institute of Physicotechnical and Radiotechnical Measurements

[Abstract] A tunable dye laser is considered with which a collinear optoacoustic filter energized by controllable microwave power and placed inside the resonator cavity serves as tuning element (O. J. Taylor, S. E. Harris, S. T. K. Nieh, T. W. Hansch APPLIED PHYSICS LETTERS Vol 19, 1971). The optical system includes, in addition to the filter, an orthogonally polarizing Rochon prism and an end mirror on each side of the "active medium - potoacoustic filter" system. Optical and acoustic waves interact parametrically in the filter and some of the laser radiation, reflected and polarized, is fed back to the active medium. The necessary condition for emission is established in terms of optical gain in the active medium and efficiency of parametric interaction in the filter, whereupon the performance characteristics of such a laser, particularly the diffraction efficiency, are calculated. An experiment was performed with rhodamine 6G as active medium and a quartz crystal as optoacoustic filter (tuning range 0.4-0.8 μm, bandwidth 3.0-5.0 Å, power efficiency 0.7 maximum and controllable through regulation of the microwave input over the 1-20 W range). The active medium was pumped with radiation from an INP2-5/75 flash lamp. The emission spectrum was found to be notched, an indication of high sensitivity, owing to the intrinsic resonance characteristics and 400 kHz frequency separations of the filter. The authors thank V. M. Zakharov and Yu. K. Kalinnikov for assistance in tuning the optoacoustic filter. Figures 2, references 5: 2 Russian, 3 Western.
[47-2415]

CO_2-LASER WITH RADIOISOTOPE PREIONIZATION

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 5, 12 Mar 83 (manuscript received 25 Oct 82) pp 284-288

LAVRENTYUK, V. Ye., PODMOSHENSKIY, I. V. and ROGOVTSEV, P. N.

[Abstract] A pulsed CO_2-laser has been built and tested, with preionization of the active medium by α-particles from plutonium sources. The energy of

α-particles here exceeds 5 MeV, sufficient for them to penetrate 10 cm into a gaseous medium such as CO_2 under atmospheric pressure. The dose of γ-radiation is four orders of magnitude below the tolerance level so that no protective shielding is required. The laser operates with transverse excitation from complete discharge of a noninductive capacitor through a preionized 16 mm gap. Solid aluminum electrodes and flat capsules containing radioactive sources with an activity of approximately 0.08 mCi/cm^2 are placed inside a chamber with dielectric walls which, after evacuation, has been filled with a prepared CO_2:N_2:He gas mixture. The path-of-flight of α-particles is always longer than the distance between their sources. With self-sustained volume always longer than the distance between their sources. With self-sustained volume discharge it is possible to generate current pulses of 30 A/cm^2 (1.5 μs duration) to 120 A/cm^2 (0.35 μs duration), depending on the electric field intensity. A pumping energy of 200-250 $J/(dm^3 \cdot atm)$ is attainable and an overall laser efficiency of 2-3.5% is attainable, the latter depending on the electric field intensity as well as on the gas composition and pressure. Figures 27, references 4: 3 Russian, 1 Western.
[47-2415]

NUCLEAR PHYSICS

EMISSION OF SECOND HARMONIC AND MEASUREMENT OF COMPRESSION RATE IN CASE OF SHELL TARGETS WITH LARGE ASPECT RATIOS

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 37, No 8, 20 Apr 83 (manuscript received 4 Feb 83) pp 359-362

BASOV, N. G., KALASHNIKOV, M. P., MIKHAYLOV, Yu. A., OSIPOV, M. V., RUPASOV, A. A., SKLIZKOV, G. V., FEDOTOV, S. I, and SHIKANOV, A. S., Institute of Physics imeni P. N. Lebedev, USSR Academy of Sciences

[Abstract] Compression of glass and polystyrene shells with large aspect ratios $A_s = R_0/\Delta_0 > 100$ (R_0 - radius, Δ_0 - thickness) in the "Del'fin-1" laser apparatus was studied experimentally by methods used for diagnosis of plasma dynamics near the critical density ($n_{cr} \sim 10^{21}$ cm^{-3}). A radiation flux density $q_0 \lesssim 5 \cdot 10^{13}$ W/cm^2 in pulses of 2.3 ns duration at the target surface was produced by six compounding laser beams with a total energy of 1 kJ, approximately half the energy being absorbed. The spectrum of the heating laser radiation was 100 Å wide at the 50%-intensity level, with the peak at the λ_0 = 10,598 Å wavelength. The spectrum of the second harmonic generated in the plasma was 50 Å wide, with Doppler shift of the peak 5299 Å by 5-12 Å toward longer waves. Only 10^{-6} - 10^{-5}% of the laser energy was transferred to the second harmonic. The maximum compression rate according to this Doppler shift of the second harmonic was $2.75 \cdot 10^7$ cm/s. It was $3 \cdot 10^7$ cm/s according to data obtained by scanning the x-ray images of the plasma in time and by plotting the trajectory of inward shell movement, the mean compression rate being here $1.4 \cdot 10^7$ cm/s. The results do not quite agree with those based on scaling the results of measurements made in the "Kal'mar" laser apparatus on such shells with small aspect ratios $A_s < 30$, because of the different compression dynamics in each case. Figures 3, references 6 Russian.
[45-2415]

X-RAY IMAGES AND COLLAPSE TIME OF GAS-FILLED GLASS MICROSPHERES WITH ASPECT RATIO OF 100-200 AFTER ENERGY INPUT OF 0.2 J/ng

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 37, No 7, 5 Apr 83 (manuscript received 21 Jan 83, after revision 28 Feb 83) pp 328-331

VOLENKO, V. V., IVANOV, A. F., MYALITSIN, L. A., OSADCHUK, L. A. and SAUKOV, A. I.

[Abstract] Increasing the specific laser energy input to a target above 0.1 J/ng is necessary for increasing the neutron yield, but is feasible only with targets having a very small mass and a large aspect ratio $R/\Delta R$ (R- radius of sphere). Using thin shells as targets is problematic, inasmuch as increasing their aspect ratio results in appreciable short-wave symmetry distortions and possibly loss of stability under adiabatic compression. A series of experiments was performed in the "Sokol" apparatus, using targets with a mass of 40-60 ng and aspect ratios from 100 to 200. The nonuniformity of target illuminance was $\pm$10%, that of laser energy absorption only $\pm$5%. An energy input of 0.2 J/ng was reached, at which the target collapse time ranged from 0.9 to 1.2 ns. All integral x-ray image densitograms revealed a central glow of targets, but only at the 1.3 keV quantum energy level with the aspect ratio within the 100-170 range and also at the 2.6 keV quantum energy level with $R/\Delta R \gtrsim 170$, also at the 3.5 keV quantum energy level in the case of a symmetric target. The results indicate the feasibility of obtaining necessary compression ratios with such targets and of finding optimum targets for laser-driven fusion within a wide range of aspect ratios. Figures 4, references 9: 4 Russian, 5 Western. [44-2415]

BREMSSTRAHLUNG FROM ELECTRONS IN ATOMIC POTENTIAL: CLASSICITY OF SPECTRUM AND SIMILARITY LAWS

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 37, No 6, 20 Mar 83 (manuscript received 14 Feb 83) pp 272-275

KOGAN, V. I. and KUKUSHKIN, A. B., Institute of Atomic Energy imeni I. V. Kurchatov

[Abstract] The theory of bremsstrahlung from electrons in the approximation of a static atom potential is applied to the problem of determining the integral (with respect to the photon emission angle) bremsstrahlung spectrum. A classical description has been found to be approachable for keV energy levels on the basis of the Thomas-Fermi model of a many-electron atom, with $1/\varepsilon \sim Z^{4/3}E$ (Z- atomic number, E- electron energy in atomic units) as the quasi-classicity parameter. Tedious numerical computations for a complete classical description are avoided by considering the two extremes, both

readily admitting analytical treatment. At the zero-frequency "transport" limit the Gaunt factor in terms of cross section for elastic scattering can be calculated analytically when $\varepsilon \leq 10^{-2}$ or $\varepsilon >> 1$. At the high-frequency limit a unique relation between bremsstrahlung frequency and angular velocity of the electron emitting it when located closest to the center of the field allows using a "rotational" approximation. Similarity laws are established on this basis for comparative evaluation of quantum and classical parameters, also for evaluating the short-wave edge ($\omega_{max} = E/\hbar$) of the bremsstrahlung spectrum. The authors thank V. I. Gervids for valuable collaboration, A. G. Zhidkov for mentioning an important reference (M. Semaan and C. Quarles in Phys. Rev. Vol. 26A, 1982) and V. S. Lisitsa for discussing the results.
Figures 3, references 8: 5 Russian, 3 Western.
[43-2415]

UDC 621.039.66+537.531:543.42

USE OF HIGH-GRADE CRYSTALS FOR X-RAY DIAGNOSTICS IN STUDY OF LASER-DRIVEN FUSION

Moscow TRUDY ORDENA LENINA FIZICHESKOGO INSTITUTA imeni P. N. LEBEDEVA AKADEMII NAUK SSSR: VZAIMODEYSTVIYE LAZERNOGO IZLUCHENIYA S TERMOYADERNYMI MISHENYAMI in Russian Vol 133, 1983 pp 189-223

GOETZ, K., FOERSTER, E. and ZAUMSEIL, P., Friedrich Schiller University Jena (GDR) KALASHNIKOV, M. P., MIKHAYLOV, Yu. A., RODE, A. V., SKLIZKOV, G. V. and FEDOTOV, S. I.

[Abstract] X-radioscopy is an effective method of diagnosing the targets and the plasma of target material during experiments with laser-driven fusion, crystals being required for the spectrograph which will not only ensure a high spectral and space resolution but also cover a wide range of wavelengths. A spectrograph with plane crystal is preferable to a focusing spectrograph or to one with convex crystal, because its luminosity at a fixed source-crystal distance does not depend on wavelength, frequency range, and crystal geometry: $d\gamma/d\theta=const=1$ (γ- divergence angle, θ- Bragg angle), also because its resolution is the maximum attainable on account of zero surface curvature. Plane crystals are easiest to produce without lattice distortion from any material, quartz and silicon being the most suitable materials for this application. The spectroscopic characteristics of quartz crystals with revlection by the (1010)-plane and of silicon disks (single crystals) with flat surfaces in (111)-plane have been measured for quality control and spectrograph optimization in terms of theoretical radiation intensity as well as spectral and space resolution. The performance of quartz and silicon X-ray spectrographs was comparatively evaluated in experiments with aluminum, silicon, sulfur and phosphorus targets. The space resolution of the quartz crystal was checked against the spectrum of He-like Al-XII aluminum ions, that of the silicon crystal was checked against the spectrum of H-like Si-XIV silicon ions and He-like S-XV sulfur ions. The feasibility of forming a two-dimensional target image in the light at the wavelength of its intrinsic emission line with a high space

resolution was established, with a phosphorus target, by producing a photograph of two plasma flares separated by means of a laser-beam splitting optical wedge. The reflection characteristics of real quartz and silicon crystals were measured, and the results correlated with the dynamic theory of X-ray interference for scattering by an ideal single crystal under three possible conditions: 1) primary extinction strong and absorption weak; 2) extinction and absorption approximately equal; 3) extinction weak and absorption strong. With these data available, a method of measurement has been developed for the absolute intensity of line-spectrum radiation from a plasma. The theory of this method, based on photon count, has been applied to experiments with plasma heating by laser radiation with flux density of the order of 10^{14} W/cm^2. Also an X-ray schlieren method has been developed, for inspection of targets used in experiments with laser-driven fusion. This method, based on the geometrical-optics approximation with physical-optics correction for diffraction and chromatic aberration, can be optimized as a tradeoff either between a large shift of the Bragg angle with simple interpretation of topograms and a long exposure time or between a small shift of the Bragg angle with high intensity in the plane of recording and a difficult readout requiring higher precision of intensity measurement. The first alternative was explored as possibly the preferable one. Experimental results obtained by this version of the X-ray schlieren method with the optimum configuration were compared with and calibrated against measurements made with a scanning electron microscope, by microradiography, and by two methods of optical interferometry. While ensuring a comparable accuracy ($\pm$0.15 μm), the X-ray schlieren method offers two advantages over optical interferometry: it does not require that the target material be transparent and the shell thickness can be measured directly on account of almost rectilinear propagation of X-rays. The accuracy of this method can be further improved by reduction of the distance from target to photographic film, a higher magnification, and microphotothermal treatment with calculation of intensity profiles. An accuracy within $\pm$0.05-0.1 μm appears to be feasible. The authors thank Academician N. G. Basov for his undiminishing attention and professor D. Unangst for helpful discussions, also A. Christoff and Dr. U. Alter of the "Karl Zeiss" Works in Jena for assistance in preparing crystal specimens, professor A. Meisel and Dr. H. Sommer of the Karl Marx University in Leipzig for offering the facilities of their laboratory for certain measurements, and E. Knoll, M. Rabold, A. A. Galichem and V. N. Puzyrev for assistance. Figures 32, tables 2, references 59: 28 Russian, 31 Western.
[42-2415]

UDC 621.378.9:533.9.02

DYNAMICS OF PLASMA CORONA ON SPHERICAL TARGETS UNDER LASER RADIATION

Moscow TRUDY ORDENA LENINA FIZICHESKOGO INSTITUTA imeni P. N. LEBEDEVA AKADEMII NAUK SSSR: VZAIMODEYSTVIYE LAZERNOGO IZLUCHENIYA S TERMOYADERNYMI MISHENYAMI in Russian Vol 133, 1983 pp 146-188

ZAKHARENKOV, Yu. A., ZOREV, N..N., RUPASOV, A. A., SKLIZKOV, G. V. and SHIKANOV, A. S.

[Abstract] Experiments were performed for a study of interaction of laser radiation and plasma corona, specifically the effect of laser radiation on the hydrodynamics of plasma dissipation and corona formation during the first two stages: evaporation and compression. Solid microglobules of glass (SiO_2) and tin as well as spherical microshells of silica, alumina, and polystyrene (C_8H_8), 70-25 μm in diameter, were used for irradiation with laser pulses of up to 200 J energy and 2 ns duration in the "Kal'mar" equipment with a special high-speed optical diagnostic system. The latter included a ruby laser or a neodymium laser with a frequency doubling KDP crystal, an optical delay line, a Jamin interferometer, an objective lens, a semitransparent mirror, a displacement interferometer, another lens and a set of mirrors, an interference-type light filter, a discharger with laser ignition, a photoelectric recording device, a focusing-on-target lens, beam splitters, and a multiframe interference-type photographic camera. This instrumentation tracked the evolution of the density profile and the dynamics of density perturbations in the corona so that the hydrodynamic parameters and the effect of perturbations on corona dissipation could be determined. The critical-density region and its kinetics were recorded and measured photographically with both space and time resolution, its velocity being determined from the second-harmonic radiation and its electron temperature being determined from the 3/2-harmonic radiation. The energy spectrum of plasma ions, namely their charge and velocity distributions, was measured with special equipment including ion collectors with negatively biased grids in grounded housings, an electrostatic ion analyzer, and a secondary-emission multiplier. Fast ions moving in a jet through spherically adiabatically expanding plasma were recorded by both interferometry and schlieren photography. The results of these experiments are now evaluated and analyzed from the standpoint of hydrodynamic theory of laser plamsa, including various models of density profile deformation and charged-particle acceleration such as resonant acceleration of ions near the critical-density region. Figures 35, table 1, references 119: 58 Russian, 61 Western.
[42-2415]

UDC 621.378.9:533.9.02

HEATING AND COMPRESSION OF SPHERICAL TARGETS BY LASER RADIATION

Moscow TRUDY ORDENA LENINA FIZICHESKOGO INSTITUTA imeni P. N. LEBEDEVA AKADEMII NAUK SSSR: VZAIMODEYSTVIYE LAZERNOGO IZLUCHENIYA S TERMOYADERNYMI MISHENYAMI in Russian Vol 133, 1983 pp 51-145

VASIN, B. L., YEROKHIN, A. A., ZOREV, N. N., KOLOGRIVOV, A. A., RUPASOV, A. A., SKLIZKOV, G. V. and SHIKANOV, A. S.

[Abstract] Two important processes in laser-driven fusion are radiation absorption by the target through various mechanisms and plasma compression, the latter limited by hydrodynamic instabilities. Prototype laser power equipment for experimental study of these processes was built in 1971, furnished with a series-parallel amplification system, and finally modified in 1974 into the "Kal-mar" 9-channel facility. The latter was subsequently improved in 1979 so that it can now operate with laser pulses of 250 J energy and brightness exceeding 10^{17} W/(cm^2·sr), the spectral composition being controllable. It consists of a master laser, a pulse shaper, a module of preamplifier cascades, a module of power amplifier cascades, a beam focusing and aiming system, and a vacuum chamber with diagnostic measuring instruments. The master laser is a YAG crystal (38 mm long rod 4 mm in diameter), replaceable with an Nd-glass rod (306 mm long and 12 mm in diameter), emitting nanosecond pulses with regular "low-frequency" modulation and irregular "high-frequency" modulation. The pulse shaper is a high-speed Kerr-effect shutter. The spectral composition of laser radiation is measured and controlled by means of a Fabry-Perot etalon and an MDR-2 monochromator with 4.0 nm/mm dispersion in the 1.06 μm band. Brightness-energy characteristics of power lasers, including beam divergence and directivity, energy contrast, pulse shape and pulse duration, were measured with this facility for optimization of the optical system. Experiments were also performed for determining the dynamics of propagation of strong shock waves, particularly under conditions of ionization and dissociation, the results having been correlated with theoretical ones based on energy balance and an equation of motion as adiabatic process. Dependence of the shock wave dynamics on the wavefront structure has been established on this basis. Plasma temperature and evaporated plasma mass during the initial stage of shock wave propagation were determined experimentally, after gas substance and gas pressure as well as method of recording the position of a shock wave had been suitably selected on the basis of theoretical considerations, with subsequent evaluation of random and systematic errors. Following these preliminary experiments, the main experiments were performed in a study of controlled laser-driven fusion using targets in the shape of spherical shells. Absorption of laser energy by such targets was measured by two calorimetric methods, the first involving measurement of the total laser energy entering the vacuum chamber as well as the energy lost in refracted and bypassing radiation, the second involving the use of two high-sensitivity probes, an open and a closed one, whose readings are compared. The second method was found to be particularly suitable and sufficiently accurate for determining the energy balance during

heating of spherical targets. Energy absorption by the plasma was also determined from the shock wave dynamics in an atomic gas, with appropriate evaluation of experimental data on the basis of thermogasdynamic laws. Scattering of laser radiation by the plasma was measured on the fundamental frequency of radiation as well as on its two harmonics, interaction of laser radiation with the plasma corona found to generate a second-harmonic spectrum at a critical radiation flux density $q_0 \simeq 10^{13}$ W/cm^2 and a 3/2-harmonic spectrum at a critical radiation flux density $q_0 \simeq 10^{14}$ W/cm^2. Finally, X-radiation and neutron radiation emitted by the plasma of such targets were studied by methods of X-ray photography and obscurogram processing. Profiles of plasma density and electron temperature in the corona as well as the rate of plasma compression were determined on the basis of these X-radiation measurements. Figures 47, tables 5, references 218: 114 Russian, 104 Western.
[42-2415]

UDC 621.375.826+62.52

CONTROL COMPUTERS AND EQUIPMENT IN SUBSYSTEMS FOR AUTOMATION OF 'DEL'FIN' FACILITY

Moscow TRUDY ORDENA LENINA FIZICHESKOGO INSTITUTA imeni P. N. LEBEDEVA AKADEMII NAUK SSSR: VZAIMODEYSTVIYE LAZERNOGO IZLUCHENIYA S TERMOYADERNYMI MISHENYAMI in Russian Vol 133, 1983 pp 19-50

ALLIN, A. P., BELEN'KIY, Yu. M., BORZYAK, Yu. V., BYKOVSKIY, N. Ye., GRIGOR'YEV, V. Ye., GUSYATNIKOV, B. S., DOROSHKEVICH, I. L., IVANOV, V. V., KUCHINSKIY, A. G., SAVCHENKO, V. M., SEMENOV, V. F., SENATSKIY, Yu. V., SKLIZKOV, G. V., SUBBOTIN, L. K., TARANCHUK, V. B., SHPILEVOY, B. N., YUZHAKOV, A. N. and YAKUSHEV, A. K.

[Abstract] An automation system is being developed for the "Del'fin" multibeam Nd-laser equipment operating at the Laser Plasma Laboratory of Lebedev Physics Institute and capable of producing nanosecond pulses of 10^4 J energy for experiments with laser-driven fusion. This automation system has a three-level architecture, with a central computer at the upper (third) level, at least three subsystems ("laser power supply", "laser beam adjustment", "laser parameters diagnosis") with a computer in each at the middle (second) level, and each subsystem computer interfaced with at least two local computers at the lower (first) level. The model for this system was the U.S. SHIVA facility at Lawrence Livermore Laboratory, the most highly automated facility of this kind. The "Del'fin" automation system includes, accordingly, a control computer complex with appropriate software in a central-panel and ring-series SH trunk with CAMAC peripheral equipment. The CAMAC equipment has been laid out and built by three firms: "Polon" (Poland), "Nuclear Enterprise" (United Kingdom) and "HENESA" (Switzerland). Two RDR-11/04 minicomputers constitute the base of the complex at the second level. The central computer, with a 28 K 16-word direct-access memory, an RK-05 2x2.5 Mbyte disk memory and an RX-01 2x256 kbyte flexible-disk memory, also a TM-11 magnetic-tape memory, operates with two alphanumeric

displays (VT-340 and LYNWOOD), a KE-11B arithmetic unit, a DL-180 matrix terminal and a DECWRITER terminal. Software can be programmed in FORTRAN-4, BASIC-11, or COBOL. Automation of the laser power supply involves the multichannel capacitor bank and the amplifier module consisting of a pre-amplifier, power stages, and three output stages in tandem. Automation of the laser beam adjustment involves the optical channel and space-angle orientation of the optical components as well as the target feed into the focal space. The aiming command module here can operate in four modes: with signals from three variable precision resistors on the target drive, with signals from coordinate photoreceiver heads, with commands from a computer, and with signals from terminal cutout switches letting the target move into extreme position along any of three coordinate axes. The latest trends in further improvement of this control computer complex are toward use of an SM-4 computer with 124 K direct-access memory at the upper level, use of "smart" crates on microcomputer (Elektronika-60) base at the lower level in various configurations most suitable for given function within given subsystem, use of optical communication lines, and use of satellite module for electric-to-optical and optical-to-electric signal conversion. Figures 31, tables 2, references 22: 16 Russian, 6 Western.
[42-2415]

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AMPLIFIER MODULE IN 'DEL'FIN' EQUIPMENT FOR HEATING THERMONUCLEAR PLASMA

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BASOV, N. G., VASIN, B. L., GALICHIY, A. A., DANILOV, A. Ye., IVANOV, B. Yu., KALASHNIKOV, M. P., KRUGLOV, B. V., MIKHAYLOV, Yu. A., OSETROV, V. P., PUZYREV, V. N., RODE, A. V., SAVCHENKO, S. M., SKLIZKOV, G. V., SOLODKOV, V. M., FEDOTOV, S. I., TSITOVICH, V. A. and SHISHKINA, L. I.

[Abstract] The "Del'fin" thermonuclear equipment for heating of targets in a spherical configuration consists of four functionally independent high-power amplifier modules, each forming 54 laser beams 45 mm in diameter with the possibility of combining them into various groups. Subnanosecond laser pulses are generated in neodymium glass with periodic Q-switching and high-precision mode locking. Nanosecond pulses are formed by a single-mode master laser with special electrooptic Kerr shutters. Pulses pass through a linear preamplifier cascade with filters containing dye solution and irised space filters inside spherical or cylindrical collimators. This preamplifier cascade forms a laser beam in pulses of 30-40 J energy and 2.4 ns duration. This beam is split into four, in two steps, each of which is then boosted to the energy level of the orginal beam. All four are sent into an amplifier module, one module consisting of a preliminary stage, a power stage of 3 cells, a power stage of 6 cells, three power stages in tandem of 6 cells each, and three output stages in tandem of 18 cells

each, with beam splitting between stages effected by means of cylindrical collimators. Accordingly, 3x18=54 beams appear at the output of an amplifier module and they can, after optical compensation of path lengths and with focusing, be variously grouped together. Diagnostic equipment includes calorimeters for measurement of radiation energy, photographic recording instruments (near field), divergence measuring instruments (far field), coaxial photocells for measurement of pulse shape, and semiconductor-type detectors for measurement of energy contrast. Each focusing channel in the target chamber consists of a multiprism mirror, a long-focus first lens, a deflecting plate, a rotatable mirror for conforming to spherical target geometry and for tautochromization, and a short-focus second lens before the target. Laser radiation is concentrated on the target by means of this focusing and an aiming system, a test-target mirror serving as monitor with television hookup. Measurements showed the distribution of radiation intensity over sections in various beams along the amplifier module, the structure of light spots, the dependence of beam divergence on energy output of the active medium of an amplifier cell and on the time interval between successive laser flashes. At a pumping energy of 25 kJ for each amplifier cell (rod 560 mm long and 45 mm in diameter), the amplifier module can deliver a total laser energy of 1000 J in 54 beams and pulses of 2.4 ns duration, with a flux density of 0.6 GW/cm^2, a brightness of 10 10^6 GW/(cm^2·sr) and with an emission divergence of $3.9 \cdot 10^{-4}$ rad. An experiment with heating of plasmas was performed for the purpose of determining the performance of such an amplifier module as well as the relation between structure of the target plasma and parameters of the laser radiation. Aluminum foil 0.5-10 μm thick and SiO_2 spherical shell segments 100-300 μm in diameter were used as targets. Heating, in terms of temperature and plasma density, was monitored through bremsstrahlung and recombination radiation spectra, also through photography of a plasma in its intrinsic X-radiation and through relative intensities of components in multiple-charge ion spectra. Figures 21, table 1, references 30: 15 Russian, 15 Western.
[42-2415]

ACCELERATION OF $_{12}C^{3+}$ IONS FROM LASER PLASMA IN CYCLOTRON

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 5, 12 Mar 83 (manuscript received 18 Nov 82) pp 261-263

ANAN'IN, O. B., BYKOVSKIYL, Yu. A., GIKAL, B. N., GUSEV, V. P., KOZYREV, Yu. P., KOLESOV, I. V., KUTNER, V. B., OGANESYAN, Yu. Ts., PASYUK, A. S., PEKLENKOV, V. D. and UZIYENKO, D. A.

[Abstract] The feasibility of producing a laser source of ions was established in 1969 (USSR patent disclosure No 324938, BYULLETEN' OIPOTZ No 7, 1974) and the feasibility of using it in a cyclotron was established in 1973. An orginal experiment was subsequently performed with such an ion source and a complete cycle of ion acceleration. Radiation

pulses of 0.4 J energy emitted from a CO_2-laser with transverse discharge at a repetition rate of approximately 1 Hz were injected into a U-200 isochronous cyclotron through a vertical channel in the pole piece of the electromagnet and focused on a target at the center of the cyclotron so as to produce a radiation flux density of the order of 10^9 W/cm^2 at the surface of the latter. Carbon ions $_{12}C^{3+}$ were selected as most suitable for such an experiment. The integral ion current at the output of the source was 1-3 A, with a density of approximately 10 A/cm^2, in pulses of approximately 2.5 μs duration and thus much longer than the laser pulses (evidently as a result of a shift of the energy spectrum of ions toward lower energy during passage of the plasma from target to emission slot and cutting magnetic lines of force in the process). The fast-ion current was approximately 1 mA with $(1-3)\cdot10^9$ ions per laser pulse at a distance of 30 cm from the cyclotron center, the duration of a fast-ion pulse being 1.5 μs. The intensity of the ion beam impinging on the foil at the cyclotron output was, after charge transfer, $(4-9)\cdot10^8$ ions per laser pulse. The authors thank G. N. Flerov for formulating the problem and constant involvement, also Ye. A. Korchagin and A. G. Pil'kov for technical assistance in setting up the experiment. Figure 1, references 7 Russian. [47-2415]

OPTICS AND SPECTROSCOPY

DIODE SPECTROSCOPY OF SF_6 MOLECULES COOLED IN PULSATING JET DURING MANY-PHOTON INFRARED EXCITATION

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI
in Russian Vol 37, No 8, 20 Apr 83 (manuscript received 22 Feb 83)
pp 365-368

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[Abstract] Many-photon excitation of SF_6 molecules in a strong infrared laser field and the mechanism of entrainment during interaction were studied by the method of infrared-infrared double resonance, in an experiment with a pumping CO_2 pulse laser and a probing variable-frequency PbSnSe-diode pulse laser. This method is characterized by a high spectral resolution (10^{-3}-10^{-4} cm^{-1}) and by a high sensitivity, the latter allowing operation at low gas pressures ($<10^{-3}$ mm Hg) and thus in the almost collisionless mode of excitation. The molecules of SF_6 were cooled in a pulsating jet to a rotational temperature $T_{rot} \leq 40$ K and a vibrational temperature $T_{vib} \simeq 160$ K. The time delay between pumping and probing laser pulses was minimized with the pumping radiation and the cooling jet in a coaxial counterflow arrangement. The probing radiation was tuned over the 946.3-948.2 cm^{-1} band at a rate of $(2\text{-}3)\cdot 10^{-3}$ $cm^{-1}/\mu s$, completely covering the frequency range of P and Q branches of the $\nu_3 = 1 \leftarrow \nu_3 = 0$ transition. Oscillograms of the probing-laser absorption spectra, indicating a decrease of absorption and a transillumination of P(10), P(9) multiplets, revealed a depletion of the rotational sublevels in the vibrational ground state of an SF_6 molecule by radiation pulses from the CO_2 pumping laser. The fraction of molecules excited from individual rotational sublevels (and of those remaining unexcited) was measured as a function of the pumping pulse energy density over the 0.01-1.3 J/cm^2 range, also as a function of the pulse repetition rate. The pattern of interaction with all rotational states is attributed to a dominant role of direct many-photon transitions, including high-order ones, within the range of lower discrete levels. The authors thank V. G. Koloshnikov and V. S. Letokhov for support and interest, and A. A. Makarov for helpful discussion of the results. Figures 3, references 7: 5 Russian, 2 Western.
[45-2415]

ROLE OF ELECTRON INJECTION IN FORMATION OF OPTICAL IMAGES IN $Bi_{12}SiO_{20}$ CRYSTALS

Leningrad PIS'MA V ZHURNAL TEKHNICHESKOY FIZIKI in Russian Vol 9, No 7, 12 Apr 83 (manuscript received 4 Feb 83) pp 385-390

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[Abstract] The dynamics of electric field distribution in a $Bi_{12}SiO_{20}$ crystal of a PRIZ space-time modulator during recording and processing of optical images are analyzed taking into account the role of electron injection, a characteristic feature being the buildup of the electric field at the negative electrode with a narrow weak-field region forming deeper in the crystal. The dipole moment as a function of time is calculated theoretically on the basis of specimen and field geometry. It is also determined experimentally from profiles of electric field intensity over the thickness of a 10x4.5x0.7 mm crystal. These profiles were measured with the aid of the transverse electro-optic effect, after exposure to recording light from an He-Cd laser (λ = 441 nm) or a sodium lamp (λ = 589 nm), with or without ultraviolet intensification controlling the level of electron injection from transparent wide surface electrodes. The results reveal several anomalities in the field distribution dynamics associated with electron injection. As the injection current increases, the steady-state electric field intensity at the illuminated electrode decreases and the dip in the field profile shifts toward the negative electrode. At the same time, the electric field intensity and consequently also the dipole moment at the positive electrode become nonmonotonic functions of time: they first decrease to a minimum and then increase. For efficient operation of the modulator, therefore, a blocking contact is required on the negative electrode. Figures 4, references 6: 5 Russian, 1 Western. [49-2415]

USING METHOD OF RESONANT FLUORESCENCE FOR DIAGNOSIS OF PLASMA NEAR WALL OF DISCHARGE CHAMBER IN 'TUMAN-3' APPARATUS

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI in Russian Vol 37, No 7, 5 Apr 83 (manuscript received 14 Feb 83) pp 308-310

BURAKOV, V. S., MOSHKALEV, S. A., NAUMENKOV, P. A., RAZDOBARIN, G. T., SEMENOV, V. V., TALYBOV, V. M. and TARASENKO, N. V., Physico-Technical Institute imeni A. F. Ioffe, USSR Academy of Sciences; Institute of Physics, BSSR Academy of Sciences

[Abstract] The "Tuman-3" apparatus, a tokomak for study of combined adiabatic plasma compression on inside (radius 25 cm) and outside (radius 55 cm) by a rising magnetic field, was used for experiments in diagnosis of a plasma near walls of the discharge chamber by the method of resonant fluorescence. The walls of the discharge chamber, all metal, were made of 1,2 mm thick nichrome. The diaphragm was 1-1,2 cm high. The longitudinal magnetic field was 0.3-0.4 T strong during Joule-effect heating with a current of 70 kA and reached 0,9 T during adiabatic compression. The electron concentration was approximately 10^{13} cm^{-3}. Fluorescence of Fe and Ni atoms near the walls was excited and recorded with special equipment, from separate levels of the respective fine structures Fe I α^5D and Ni I α^3F. The minimum recordable concentration of Fe atoms was $3 \cdot 10^6$ cm^{-3}, the sensitivity of instruments being limited principally by fluctuations of the photocurrent from the photomultiplier cathode and the noise of intrinsic plasma flow being several orders of magnitude weaker than the useful signal. The distribution of Fe-atom concentration in space and time was measured under conditions of saturated optical transition, the concentration found to reach the maximum of approximately $2 \cdot 10^7$ cm^{-3} during the middle stage of discharge in the Joule-effect heating mode and to decrease appreciably during adiabatic compression. The concentration of Ni atoms was also measured by the same method under analogous conditions, and found to reach a maximum of $(2-3) \cdot 10^7$ cm^{-3}. The authors thank V. Ye. Golant for interest in this study and the "Tuman-3" staff for assistance in the experiments. Figures 2, references 3 Western. [44-2415]

EMISSION OF HIGH-ORDER HARMONICS OF HIGH-POWER LASER RADIATION IN PLASMA

Moscow PIS'MA V ZHURNAL EKSPERIMENTAL'NOY I TEORETICHESKOY FIZIKI
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[Abstract] Emission of high-order harmonics of laser radiation in a plasma heated by a CO_2-laser is examined from the standpoint of mechanisms which generate these harmonics. According to the theory of weak nonlinearity, there is an inverse exponential dependence of the emission intensity on the order of harmonic. Emission of high-order harmonics in this case of finite nonlinearity can be effected by a discontinuity mechanism, an example being umklapp of electron flux resulting in a power-law dependence of the emission intensity on the order of harmonic. Two illustrations of this are radiation emitted furing umklapp of a nonrelativistic electron beam in a homogeneous plasma and emission of even more intense dipole radiation during collision of an umklapped electron wave with a perturbation of the ion concentration. References 8: 5 Russian, 3 Western.
[44-2415]

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